Dynamic Response of Local Layer and Molecular Orientation in Smectic Liquid Crystals by Time Resolved X-ray Micro-Diffraction

Dept. of Physics, Nihon Univ.[1]
Institute of Materials Structure Science, High Energy Accelerator Research Organization[2]
Dept. of Organic and Polymeric Materials, Tokyo Institute of Technology[3]
Yumiko Takahashi[1*], Atsuo Iida[2], Yoichi Takanishi[3],
Hideo Takezoe[3], Kouichi Takase[1], Yoshiki Takano[1] and Kazuko Sekizawa[1]

キラル分子からなるスメクティック液晶のSmA*相では、電場によって配向ベクトルの傾き角が誘起される電傾効果が観察される。電傾効果における局所層構造としてこれまで水平シェブロンを基本構造とするモデルが提案されてきたが、放射光時分割マイクロビームX線回折法により、垂直シェブロンと水平シェブロンが空間的に交互に現れるストライプ構造であることが分かった。また分子配向の変化をハローパターンから直接的に求め、層構造と分子配向の関係を明らかにした。

1 Introduction

Chiral smectic-A (SmA*) liquid crystals exhibit an electroclinic effect, wherein the electric field induces molecular tilt accompanied by the layer deformation [1]. The electroclinic effect is the fastest electro-optical effects in liquid crystals. Since the smectic layer shows sometimes complicated minute structures such as a stripe texture, the direct observation of the local layer structure with a spatial resolution of a few μm and temporal resolution less than ms is desirable to study the electroclinic effect. In this study, dynamic local layer structure and local molecular orientation in the electroclinic effect were analyzed with a time resolved X-ray micro-diffraction.

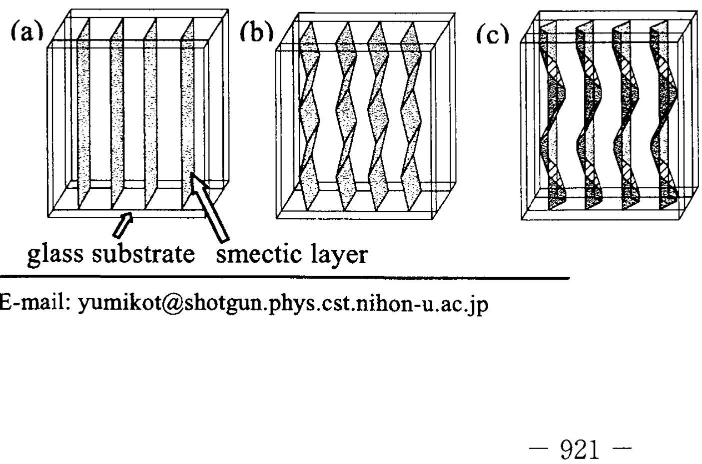

Figure 1: Schematic representation of smectic layer configurations in SmA* phase: bookshelf (a), horizontal chevron (b) and horizontal chevron + vertical chevron (c) structures.

*E-mail: yumikot@shotgun.phys.cst.nihon-u.ac.jp

2 Experimental

The experiment was carried out on BL-4A at the PF, KEK. X-rays were focused down to about 3×4 μm^2, which is smaller than the stripe width. A position sensitive proportional counter and a CCD X-ray camera with a gated image intensifier were used for the layer and intra-layer molecular response measurement, respectively. The samples were ferroelectric liquid crystals (TK-C101) and measured at T_c+0.1°, where T_c is the phase transition temperature from SmC* to SmA* (56°C).

3 Results and Discussion

In the SmA* phase, the well-known bookshelf structure was realized without field application (Fig. 1(a)). At the high AC electric field, the local layer structure transformed repeatedly between the combination of the deformed horizontal chevron and the vertical chevron (at ±20 V, Fig. 1(C)) and the quasi-bookshelf structure (at 0 V) [2]. This result is in contrast to the previous model of the simple horizontal chevron (Fig. 1(b)). The intra-layer order of the molecular arrangement observed by the time resolved halo pattern (Fig.2) showed the change of molecular orientation depending on the electric field as shown in Fig.3. In addition, the spatially-alternate molecular orientation corresponds to the layer deflection.

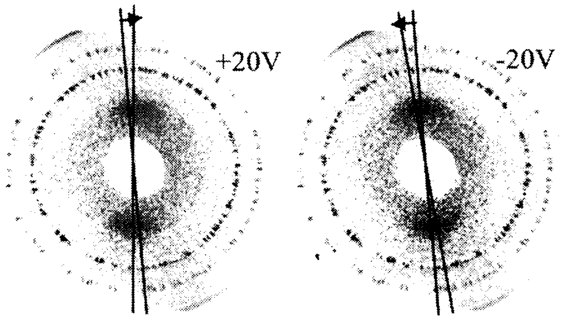

Figure 2: Time resolved micro X-ray halo patterns (short arcs at the upper and lower sides) Time resolution 25 ms.

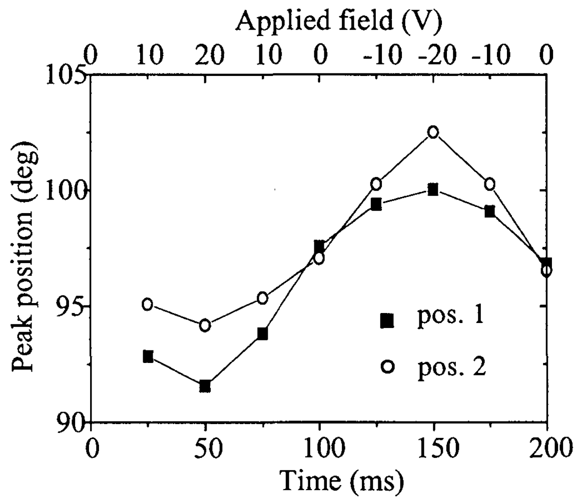

Figure 3: Peak angular positions of the halo pattern as a function of time and applied voltage. Distance between pos. 1 and pos. 2 is 5μm, corresponding to the adjacent stripes.

With the time-resolved X-ray micro-diffraction, the relation between the local layer deformation and the molecular orientation in the electroclinic effect was revealed for the first time.

References

[1] S. Garoff and R. B. Mayer, Phys. Rev. Lett. **38** (1977), 848

[2] Atsuo Iida et al., Liquid Crystals **32** (2005), 717